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(54) Alkali- and heat-resistant inorganic fiber,

(57) The inorganic fiber of this invention comprising as major constituents

| | %by weight |
|--------------------------------------|------------|
| SiO ₂ | 40-50 |
| CaO | 0-10 |
| MgO | 15-25 |
| Fe ₂ O ₃ + FeO | 0-10 |
| Al ₂ O ₃ | 5-15 |
| MnO | 2-15 |

(provided that the total amount of CaO, Fe₂O₃, FeO and MnO is limited within 20% by weight) is excellent in alkali- and heat-resistances and is useful as a replacement of asbestos in asbestos-cement boards.

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ALKALI- AND HEAT-RESISTANT INORGANIC FIBER

1 BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

This invention relates to an alkali- and heat-resistant inorganic fiber and, more particularly, to
5 alkali- and heat-resistant inorganic fibers, in which the fiberizing temperature is approximately the same as those of customary rock fibers.

DESCRIPTION OF THE PRIOR ART

Heretofore, some of glass fibers have been
10 known as alkali-resistant inorganic fibers. These glass fibers, however, show a high viscosity in the molten state such as, for example, 100 poises at 1,400°C.
Owing to such high viscosity, it is unable to manufacture short fibers by a multirotor spinning process, which
15 operates only under low melt viscosity conditions as in the case of rock fibers with a viscosity of several poises at 1,400°C. Moreover, there are other disadvantages for producing the alkali-resistant glass fibers. It is necessary to add zirconium oxide, which is expensive
20 and, furthermore gives rise to an increased melting cost.

There has recently been disclosed alkali-resistant rock fibers which dispense with expensive zirconium oxide used in conventional alkali-resistant glass fibers [Japanese Patent Application "Kokai"

1 (Laid-open), No. 101,922/1979]. The disclosed fibers,
however, have considerably high fiberizing temperature,
comparing with those of customary rock fibers. This
causes a remarkable increase in energy cost for manu-
5 facturing fibers of optimal diameter by means of a
multitrotors.

SUMMARY OF THE INVENTION

An object of this invention is to provide the
alkali- and heat-resistant inorganic fiber manufactured
10 by utilizing those natural rocks, slags and the like
which are sufficiently available from the viewpoint of
resources.

Another object of this invention is to provide
the alkali- and heat-resistant inorganic fiber which
15 can be manufactured economically by multitrotor spinning
process.

According to this invention, there is provided
the alkali- and heat-resistant inorganic fibers compris-
ing as major constituents

| | % by weight |
|--------------------------------------|-------------|
| SiO_2 | 40 - 50 |
| CaO | 0 - 10 |
| MgO | 15 - 25 |
| $\text{Fe}_2\text{O}_3 + \text{FeO}$ | 0 - 10 |
| Al_2O_3 | 5 - 15 |
| MnO | 2 - 15 |

- 1 (provided that the total amount of CaO , Fe_2O_3 , FeO
and MnO is limited within 20% by weight).

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 shows an electron microscopic photo-
5 graph of the rock fiber specimen of Comparative Example
1 in Table 1, which has been subjected to the alkali
resistance test.

Fig. 2 shows an electron microscopic photo-
graph of the alkali- and heat-resistant rock fiber
10 specimen of this invention (Example) in Table 1, which
has been subjected to the alkali resistance test.

DETAILED DESCRIPTION OF THE INVENTION

When one intends to obtain simply good fibers
from a batch material having comparatively low viscosity
15 without paying attention to the alkali and heat-resist-
ance, the SiO_2 content of the meltable material should
be in the range of 35 to 50% by weight. If the SiO_2
content is below 35% by weight, it is difficult to
obtain good short fibers of 2 to 10 μm in diameter,
20 whereas if the SiO_2 content exceeds 50% by weight, the
fiber formation by the multirotor spinning process
becomes difficult owing to an increased melt viscosity.
However, in view of the alkali and heat resistances
intended in this invention, it is desirable to increase
25 the SiO_2 content, and if the SiO_2 content is less than
40% by weight, it is difficult to obtain the fibers

- 1 having satisfactory alkali and heat resistances, relating
to the content of other alkaline oxides. After all,
it is necessary that the SiO_2 content should be in the
range of 40 to 50% by weight, most preferably 45 to
5 50% by weight.

For the purpose of improving the strength and
heat resistance of fibers, the CaO content of the
melttable material should be confined within 10% by
weight. If the CaO content exceeds 10% by weight, the
10 heat resistance, as well as physical properties of
fibers, will be lowered. The most preferable CaO content
is in the range of 0 to 6% by weight.

In the sense of replenishing the above defect
of CaO and to adjust the viscosity of the melttable
15 material to a value suitable for the multirotor spinning
process, MgO should be present in an amount of 15 to
25% by weight. If the MgO content exceeds 25% by weight,
not only the melt viscosity becomes too low to keep
the optimal fiber formation, but also to secure the
20 necessary amount of acidic oxides, resulting in lowering
the alkali resistance of the fiber. On the other hand,
if the MgO content is less than 15% by weight, the
melt viscosity becomes too high to be suitable for the
fiber formation. The most preferred MgO content should
25 be in the range of 18 to 23% by weight.

Fe_2O_3 and FeO are useful in improving the
heat resistance and flexibility of the fiber of 2 to
10 μm in diameter. However, if their content exceeds 10%

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1 by weight, the alkali resistance of the fibers will be lowered. The most preferable content of Fe_2O_3 plus FeO should be in the range of 0 to 8% by weight.

Alumina (Al_2O_3) as well as silica (SiO_2)
5 is effective in improving the fiber strength. However, with the increase in the Al_2O_3 content, the melt viscosity becomes higher and the devitrification temperature increases, resulting in an increase in melting energy cost. If the Al_2O_3 content exceeds 15% by weight, the
10 alkali resistance of the fibers will be lowered, whereas if it is below 5% by weight, good fibers may not be obtained. Therefore, the Al_2O_3 content should be restricted to the range of 5 to 15% by weight; the most preferable content is in the range of 5 to 10% by weight.

15 Manganese oxide (MnO) has favorable effects of producing a uniform melt, and also of imparting the good alkali resistance to the fibers. In the case of the rock fibers, unlike the glass fibers, the addition of 2 to 15% by weight of MnO produces a sufficient
20 decrease in melt viscosity and exhibits stabilizing and clarifying effects for the melt. For instance, the addition of 5% by weight of MnO will decrease the optimal fiber forming temperature by about 80°C . However, the addition of MnO over 15% by weight is not only un-
25 necessary but also undesirable to secure the necessary amount of SiO_2 for the optimal fiber formation. If the MnO content is below 2% by weight, the function of MnO as a flux is no longer exhibited. The most preferable

- 1 MnO content is in the range of 5 to 10% by weight.

Apart from the above-mentioned specification for each constituent, the total amount of MnO, CaO, Fe_2O_3 and FeO should be within 20% by weight, because
5 the total of 20% by weight makes the viscosity of the meltable material to the optimal level for the fiber formation by the multirotor spinning process. The superfluous addition of these constituents causes a negative factor for keeping the necessary amount of
10 SiO_2 effective for the alkali resistance.

Titanium oxide (TiO_2) is contained in natural rocks or slags to be used for the meltable material as an impurity in the amount of about 2% by weight.

- The major natural rock material to be used
15 as raw material in producing the inorganic fibers of the composition as herein specified is found in olivine and metamorphous rocks thereof containing each 35% by weight or more of SiO_2 and MgO. Olivine has an advantage of being naturally occurred anywhere throughout Japan
20 and available as raw material at low price.

A typical metamorphous rock of olivine is serpentine which can be used as a complete or partial substitute for olivine. However, as compared with olivine, generally the MgO content is smaller by about
25 5% and the Fe_2O_3 content is larger by about 3%. It is, therefore, advantageous to use olivine from the economical and other viewpoints. In order to obtain the starting material of the composition as herein specified, one needs

1 to adjust the composition of the above-noted major
natural rock material by adding the calculated amounts
of basalt, diabase, vermiculite, pyrophyllite, and
iron ore slag for SiO_2 , CaO and Al_2O_3 ; silica stone
5 and silica brick for SiO_2 ; and manganese silicate ore,
manganese carbonate ore, manganese oxide ore, and silico-
manganese slag for MgO . The selection and combination
of these natural ores or slags are not subject to any
particular restriction, unless the final composition
10 departs from that specified herein.

In manufacturing the alkali- and heat-resistant
inorganic fibers of this invention by using the said
natural rocks and slags, conventionally well-known
equipments and methods can be applied. For instance,
15 the compounded raw material is melted in a cupola by
heating at 1410° to 1460°C , the resulting melt is allowed
to flow downward onto the surface of spinning rotors
to fiberize the molten material, and the fibers formed
in this way is collected by means of an air stream blown-
20 off around the spinning rotors.

Example

The compounded raw material according to
this invention, shown in the column of Example in Table
1, was melted in a conventional cupola by heating at $1,430^\circ\text{C}$.
25 The resulting melt was allowed to flow downward onto
the surface of spinning rotors to fiberize the molten
material, and the fibers formed in this way were collected

1 by means of an air stream blown-off around the spinning
rotor.

In Comparative Examples 1 and 2, the compounded
raw materials shown in Table 1 were also formed into
5 fiber and collected in the same manner as described
above, except that the raw materials were melted at
1,460° and 1,540°C, respectively, which were the optimal
fiber forming temperatures as shown in Table 2.

Table 1

| Comparative Example 1 | Comparative Example 2 | Example |
|--------------------------|--------------------------|--------------------------|
| Slag 91% | Basalt 55% | Basalt 45% |
| Silica stone 9 | Olivine 40 | Olivine 40 |
| | Silica stone 5 | Silica stone 10 |
| | | Manganese oxide ore 5 |

The composition and characteristics of the
10 inorganic fibers obtained according to this invention
were shown in Table 2, where are also shown the composi-
tions and characteristics of other rock fibers not covered
by the present invention (Comparative Examples 1 to
3).

Table 2

| | Comparative Example 1 | Comparative Example 2 | Comparative Example 3 | Example |
|--|--------------------------|--------------------------|--------------------------|------------------|
| SiO ₂ | 39.4% | 45.0% | 47.3% | 45.8% |
| CaO | 37.4 | 16.0 | 5.4 | 5.6 |
| MgO | 5.3 | 14.9 | 23.6 | 22.3 |
| Fe ₂ O ₃ + FeO | 0.5 | 5.4 | 8.4 | 8.1 |
| Al ₂ O ₃ | 13.4 | 16.7 | 12.5 | 9.6 |
| MnO | - | - | - | 4.1 |
| TiO ₂ | 1.7 | 0.5 | 1.1 | 1.5 |
| Others | 2.3 | 1.5 | 2.6 | 3.0 |
| Melt viscosity | | | | |
| 1500°C | 4.8 poises | 9.0 poises | 5.3 poises | 3.2 poises |
| 1450°C | 6.5 | 11.0 | 6.9 | 4.5 |
| 1400°C | 8.8 | 15.3 | 11.0 | 6.4 |
| 1350°C | 14.0 | 23.0 | 30.0 | 11.0 |
| Optimal fiber- forming tempe- rature | 1430 - 1480°C | 1510 - 1560°C | 1480 - 1530°C | 1410 - 1460°C |

- Cont'd -

Table 2 (Cont'd)

| | | | | |
|--|--|--|--|---|
| Average fiber diameter | 4.2 μ | 3.7 μ | 3.5 μ | 3.3 μ |
| Alkali resistance (weight loss) | 2.0% | 1.8% | 1.0% | 1.0% |
| Appearance of fiber after alkali resistance test | Discolored, brittle and disintegrated (see Fig. 1) | Discolored; disintegrated upon touch with hand | No change in both appearance and shape | No change in both appearance and shape (see Fig. 2) |
| Heat resistance temperature | 700 - 720°C | 700 - 720°C | 840 - 860°C | 840 - 860°C |

1 Note:

- (1) All percentages are by weight.
- (2) The Comparative Example 1 indicates the customary rock fibers.
- 5 (3) The fibers of Comparative Example 2 are those of a composition not covered by the present invention.
- (4) The Comparative Example 3 correspond to the rock fibers disclosed in Japanese Patent
- 10 Application "Kokai" (Laid-open) No. 101,922/1979.
- (5) Testing method:
 - (a) Alkali resistance: 500 cc of 1 N NaOH and about 10 g (weighed precisely) of the sample are placed together in a tightly
 - 15 stoppered 1-liter polyethylene vessel and immersed in a hot water bath regulated at $80 \pm 1^\circ\text{C}$. After 24 hours, the sample is washed with clean water, dried, then measured the weight loss.
 - 20 (b) Heat-resistant temperature: A disc having a diameter of 500 mm, a thickness of 50-80 mm and a specific gravity of 0.5 is placed under a load of 10 g. The temperature of the disc is elevated at a rate of $10^\circ\text{C}/$
 - 25 minute until 500°C and then at a rate of $5^\circ\text{C}/$ minute. The temperature at which the sample has contracted in thickness by 10% is taken as the heat-resistant

1 temperature.

Fig. 1 is an electron scanning microscopic photograph (x 1,000) of the customary rock fibers after having been subjected to the alkali-resistance test
5 described in the above procedure (a). The fibers were observed to be so deteriorated to show the roughness of the fiber surface and the occurrence of dis-integrated fiber fragments.

Fig. 2 is an electron scanning microscopic
10 photograph (x 1,000) of the inorganic fibers of this invention after having been subjected to the alkali resistance test described in the above procedure (a). It was observed that the fibers was kept their original shape, neither rough surface nor fiber fragments being
15 detectable, indicating that the alkali resistance has been improved to a great extent.

As is apparent from Table 2, the fibers of this invention are superior in alkali resistance to those of the Comparative Examples 1 and 2. The fibers
20 of the Comparative Example 3 show that alkali resistance is nearly equal to those of this invention. However, the example of this invention shows the lower optimal fiberizing temperature, which indicates the possibility of a remarkable saving in the melting energy. The heat-
25 resistant temperature of the fibers of this invention is higher than that of the customary rock fibers by nearly 140°C.

- 1 The inorganic fibers of this invention having
the good alkali and heat resistances, as described
above, can be manufactured at low cost on commercial
scale and used chiefly as a replacement of asbestos
5 in asbestos-cement boards.

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What is claimed is:

1. An alkali- and heat-resistant inorganic fiber comprising as major constituents

| | % by weight |
|--------------------------------------|-------------|
| SiO_2 | 40 - 50 |
| CaO | 0 - 10 |
| MgO | 15 - 25 |
| $\text{Fe}_2\text{O}_3 + \text{FeO}$ | 0 - 10 |
| Al_2O_3 | 5 - 15 |
| MnO | 2 - 15 |

provided that the total amount of CaO , Fe_2O_3 , FeO and MnO is limited within 20% by weight.

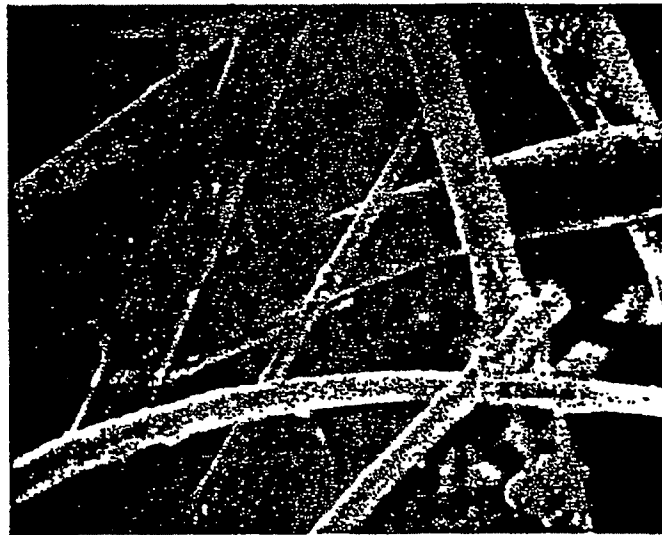
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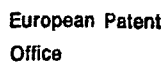
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FIG. 1



FIG. 2

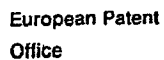




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EUROPEAN SEARCH REPORT

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| DOCUMENTS CONSIDERED TO BE RELEVANT | | | CLASSIFICATION OF THE APPLICATION (Int. Cl.) |
|-------------------------------------|--|-------------------|--|
| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | |
| | <p><u>US - A - 3 081 179</u> (F.R. CHARVAT et al.)</p> <p>* Column 1, table I; column 3, lines 19-24 *</p> <p style="text-align: center;">--</p> | | |
| A | <u>DE - A - 1 596 926</u> (NATIONAL RE-SEARCH DEVELOPMENT) | | |
| A | <u>DE - B - 1 040 444</u> (GRUNZWEIG & HARTMANN) | | |
| A | <u>GB - A - 702 059</u> (PILKINGTON) | | TECHNICAL FIELDS SEARCHED (Int. Cl.) |
| | ---- | | |
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